Unit 4

Electrical Earthing System

Introduction

Earthing or grounding plays an important role in stable and safe operation of an installed electrical system. The concept of earthing is as old as the use of electrical power in electrical appliances and loads. In early days, when ungrounded (unearthed) electrical systems or appliances were used, there was always a risk of electric shock. In order to overcome this risk, the practice of earthing started. Earthing or grounding means connecting the electrical system or equipment to the ground by means of a suitable conductor. This conductor provides a return path for the faulty current. This faulty current passes to the ground or earth through the conductor.

Electrical earthing or grounding are commonly used words for earthing. Grounding is commonly used word for earthing in North American standards like Institute of Electrical and Electronics Engineers (IEEE), National Electrical Code (NEC), American National Standards Institute (ANSI) and Underwriter's Laboratories (UL), etc., while, earthing is used in European, Commonwealth countries and British standards like British Standard Institution (BSI) and International Electrotechnical Commission (IEC). Earthing or grounding in an electrical system is invisible physically but with its working we can

feel its importance. Earthing is used to protect people from electric shocks by providing a path (protective conductor) for a fault current to flow into the earth.

Earthing is done for the safety of an electrical network. In an electrical network, all electrical parts are grounded. So, even if insulation inside an equipment fails, no dangerous voltage is present within.

Electrical earthing

The process of transferring immediate discharge of electrical energy directly to the earth with the help of a low-resistance wire is known as 'electrical earthing'.

Earthing refers to connection of the non-current carrying part of an equipment or neutral point of a power supply system to the earth or ground. It is done to avoid or minimise risks during the discharge of electrical energy.

Earthing provides a path to the leaking current. The short circuit current of the equipment passes to the earth, which has zero potential, thus, protecting the system and equipment from damage.

The metallic part of electric machinery and devices is connected to the earth plate or earth electrode (which is buried in the moist earth surface) through a thick conductor wire (which has very low resistance) for safety purpose. This set-up is known as **earthing** or **grounding**. The circuit symbol for electrical earthing is shown in Fig. 4.1

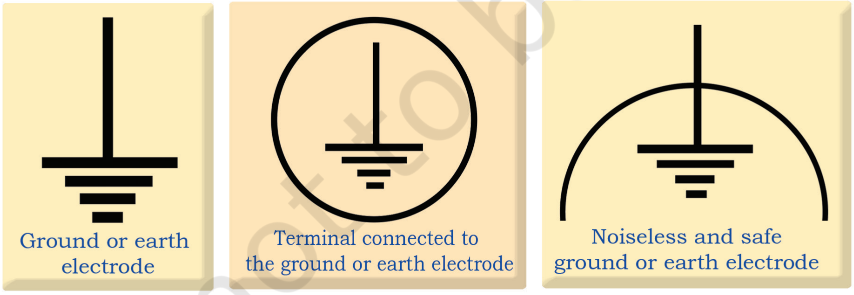

Fig. 4.1 Symbolic representation of grounding or earthing

Importance of earthing system

Every electrical equipment or appliance must be 'earthed' or 'grounded' for the safety of equipment, person and system as a whole.

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Any fault occurring in electrical supply can directly impact the human body. Major accidents happen due to faulty earthing. The leaked current may pass through the human body, which may cause severe injury or even be fatal. Earthing plays an important role in safe generation, transmission, distribution and operation of an electric system as shown in Fig. 4.2. In large power stations, the earthing resistance value is 0.5 Ohm.

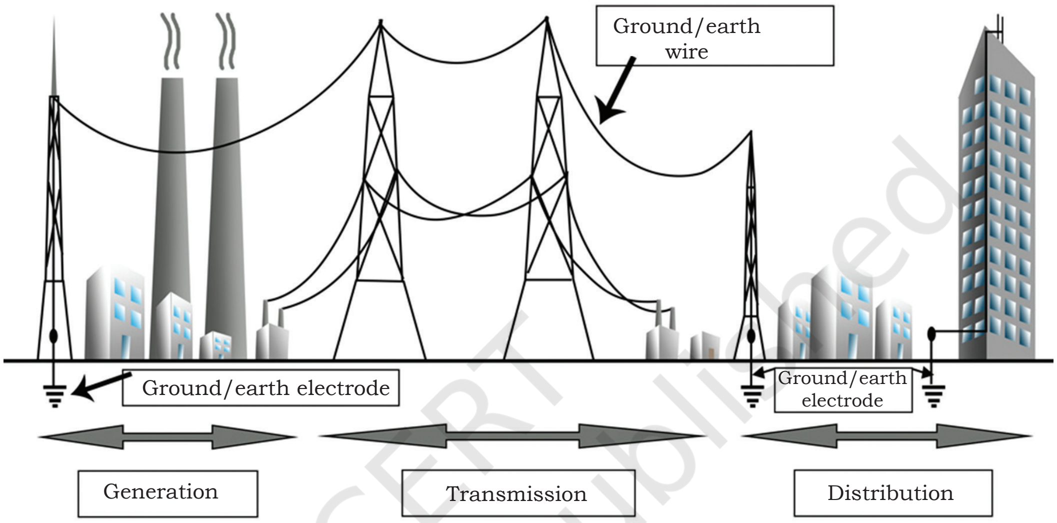

Fig. 4.2 Earthing in an electrical system

Earthing must be tested or checked at regular intervals. While testing the earthing connections, make sure that the resistance of earth connection is minimised. Record the results to improve the prescribed resistance value for better function.

Systems and purpose of earthing

The purpose of earthing can be better understood by two different systems, which are as follows.

- Ungrounded system
- Neutral grounded system

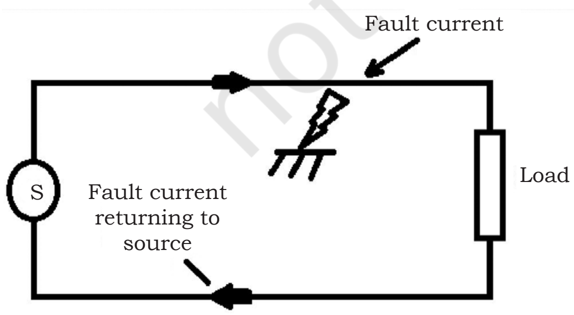

Fig. 4.3 Circuit with ungrounded system

Ungrounded system

In an ungrounded system, as shown in Fig. 4.3, the current flows from source to the load and returns to the source, thus, completing the circuit. As the circuit is not grounded, there is no path for fault

current. Due to the absence of path for fault current, it will return to the source. This will damage the source and may harm the person in contact with the circuit. This type of system is not in practice anymore.

Neutral grounded system

The solution to the issue of ungrounded system is provided by a neutral grounded system. This system avoids the risk of developing the first fault and eliminates subsequent risks of short circuiting due to second fault in the circuit. In this type of grounding, one of the poles of the source is connected to the ground mass. This is called 'neutral', while the other pole that carries the charge to the load is called 'phase'. The neutral conductor always carries the return current from the load as shown in Figs. 4.4 and 4.5.

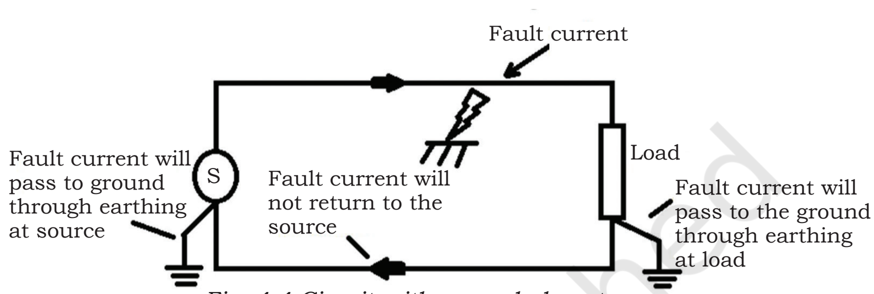

Fig. 4.4 Circuit with grounded system

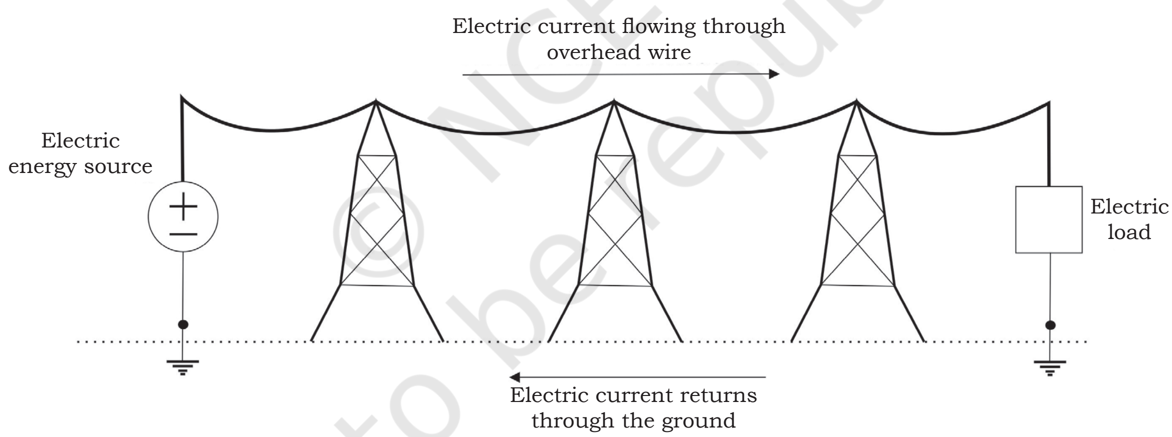

Fig. 4.5 Neutral ground system in electrical distribution system

In grounded or earthed system, neutral is connected to the earthed wire. In case of insulation failure in the phase conductor, the fault current can lead to damage in the machinery or equipment. Due to the availability of an earthed wire in the neutral line, excess fault current passes through the earthed wire to the ground surface. Through the ground path, this current safely returns to the source to complete the circuit (Fig. 4.5). Thus, by

using grounded neutral, the risk of fault current gets bypassed. This way the risk of equipment damage can be avoided. In this type of system, neutral always provides the return current path from load to the source.

We handle various electrical appliances. These appliances have some external components, which do not carry current, and hence, we can touch these parts while using these appliances. For instance, we use an electric iron to press our clothes. While electric current flows through the iron, we can still hold its plastic coated handle. This is because of earthing done in our houses.

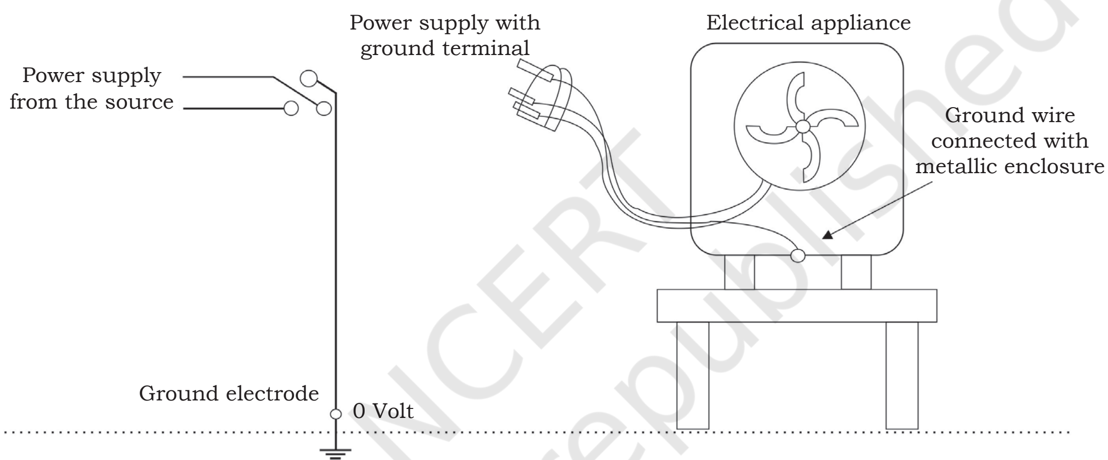

Fig. 4.6 Earthed three-pin socket of electrical appliances

The main purpose of earthing is to maintain zero potential or zero voltage of all non-current carrying metallic parts in an electrical system. When the metallic part of electrical appliances (part that can conduct or allow passage of electric current) comes in contact with a live wire due to failure of cable insulation, the metal can get charged and static charge accumulates on it. If such non-current carrying parts are not earthed, the person touching it will get electrocuted.

To avoid such an incidence, the power supply systems and parts of appliances must be earthed so as to transfer the charge directly to the earth. By earthing, the non-current carrying parts are connected to the earth and maintained at earth potential. It also prevents

static charge buildup. Also, earthing is used to release the fault current from the electrical system.

Earthing can be done by connecting the respective parts, such as electrical conductors or electrodes placed near the soil or below the ground surface. The earthing mat or electrode under the ground level has a flat iron riser through which all non-current carrying metallic parts of the equipment are connected.

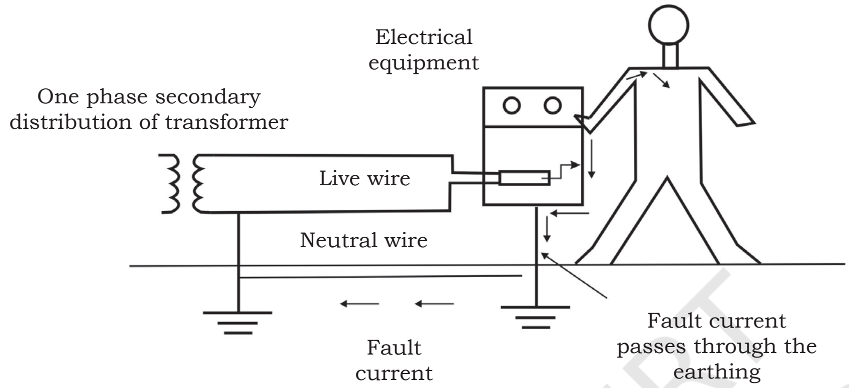

Fig. 4.7 (a) Electrical equipment with earthing

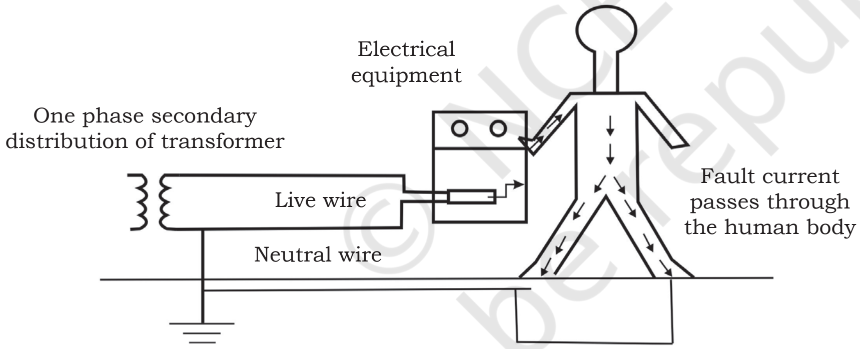

Fig. 4.7 (b) Electrical equipment without earthing

To understand the importance of earthing, let us observe a system with and without earthing as shown in Figs. 4.7(a) and (b). When a fault occurs, the fault current from the equipment flows through the earthing system to the earth, and therefore, protects the equipment from the fault current. The average resistance of human body is 500 to 1000 Ohm.

The contacting assembly is called 'earthing'. The metallic conductor connecting parts of the installation

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with the earthing is called 'electrical connection'. The earthing and the earthing connection together is called the 'earthing system'.

Types of earthing or grounding system on the basis of function

Equipment grounding

In an equipment grounding system, all non-current carrying metal parts are interconnected and connected to the earth. In this way, there is no potential or voltage between the non-current carrying parts and metal parts. Besides, there is no potential difference between the earth and non-current carrying metal parts. Non-current carrying metal parts include panel or enclosure body, metal race way, cable channel, equipment body or frame.

System grounding

In system grounding, a current carrying conductor is intentionally connected to the earthing system. This intentionally earthed current carrying conductor is called a 'grounded conductor'.

Components of earthing system

Electrical earthing system consists of the following basic components.

1. Earth continuity conductor
2. Earthing lead
3. Earth electrode

Earth continuity conductor or earth wire

Earth continuity conductor or earth wire is that part of the earthing system, which interconnects the overall metallic parts of an electrical installation. It includes conduit, ducts, boxes, metallic shells of switches, distribution boards, switches, fuses, regulating and controlling devices, metallic parts of electrical machines like motors, generators, transformers and the metallic framework, which contains electrical devices and components.

The resistance of the earth continuity conductor is very low. According to IEEE rules, the resistance between consumer earth terminal and earth continuity conductor

(at the end) must not be more than 1Ω. It means, resistance of the earth wire should be less than 1Ω.

Size of the earth continuity conductor or earth wire depends on the cable size used in the wiring circuit. The cross sectional area of the earth continuity conductor must not be less than half of the cross sectional area of the thickest wire used in the electrical wiring installation.

Earthing lead or earthing joint

The conductor wire connected between earth continuity conductor and earth electrode or earth plate is called 'earthing joint' or 'earthing lead'. The point where the earth continuity conductor and earth electrode meet is known as the 'connecting point'.

Earthing lead is the final part of the earthing system that is connected to the earth electrode (which lies underground) through earth connecting point. There should be minimum joints in earthing lead and the connecting wires should be straight in position.

Generally, copper wire can be used as earthing lead. Copper strip is also used for high installation as it can handle high fault current due to its wider area than copper wire. A hard drawn bare copper wire is also used as earthing lead. In this method, all earth conductors are connected to a common (one or more) connecting point, and then, earthing lead is used to connect earth electrode (earth plate) to the connecting point.

To make the installation safe, two copper wires must be used as earthing leads to connect the device's metallic body to the earth electrode or earth plate, i.e., if we use two earth electrodes or earth plates, there would be four earthing leads. It must not be considered that the two earth leads are used as parallel paths to flow the fault current but both the paths must work to carry the fault current for safety purposes.

Earthing electrode or earth plate

A metallic electrode or plate, which is buried in the earth (underground) and is the last part of the electrical earthing system is known as the 'earthing electrode' or

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'earth plate'. In simple words, the final underground metallic (plate) part of the earthing system, which is connected with earthing lead, is called 'earth plate' or 'earth electrode'.

A metallic plate, pipe or rod, which has very low resistance and can carry the fault current safely towards ground (earth), can be used as an earth electrode.

Grounding resistance

A minimum ground electrode length must be of 2.5 metres (8 feet) must be in contact with the soil. There are four variables that affect the ground resistance of a ground system.

1. Length and depth of the ground electrode
2. Diameter of the ground electrode
3. Number of ground electrodes
4. Ground system design

Length and depth of ground electrode

One effective way of lowering ground resistance is to drive ground electrodes deeper. Soil is not consistent in its resistivity and can be highly unpredictable.

By doubling the length of the ground electrode, one can reduce the resistance level by an additional 40 per cent. There are occasions where it is physically impossible to drive ground rods in deeper areas that are composed of rock, granite, etc. In these instances, alternative methods, including grounding cement, are viable.

Diameter of ground electrode

Increasing the diameter of a ground electrode has a little effect in lowering the resistance. For example, one can double the diameter of the ground electrode and the resistance would only decrease by 10 per cent.

Number of ground electrodes

Another way to lower ground resistance is to use multiple ground electrodes. In this design, more than one electrode is driven into the ground and connected in parallel to lower the resistance. For additional electrodes to be effective, the spacing between additional rods needs to be at least equal

to the depth of the driven rod. Without appropriate spacing between the ground electrodes, their spheres of influence will intersect and the resistance will not be lowered.

To assist students in installing a ground rod that will meet specific resistance requirements, they can refer to the table on ground resistance (Table 4.1). This is to be used only as a thumb rule because soil is in layers and is rarely homogeneous.

Ground system design

Simple grounding systems consist of a single ground electrode driven into the ground. Single ground electrode is the most common form of grounding used and can be found outside one's home or place of business. Complex grounding systems consist of multiple ground rods — connected, mesh or grid networks, ground plates and ground loops. These systems are, typically, installed at power generating substations, central offices and cell tower sites.

Complex networks dramatically increase the amount of contact with the surrounding earth and lower ground resistances (see Table 4.1).

Table 4.1 Ground resistance

Type of soil	Soil resistivity	Earthing resistance					
		Ground electrode depth (meters)			Earthing strip (meters)		
	M	3m	6m	10m	5m	10m	20m
Farming soil, clay soil	100 Ohm	33 Ohm	17 Ohm	10 Ohm	40 Ohm	20 Ohm	10 Ohm
Sandy clay soil	150 Ohm	50 Ohm	25 Ohm	15 Ohm	60 Ohm	30 Ohm	15 Ohm
Moist sandy soil	300 Ohm	66 Ohm	33 Ohm	20 Ohm	80 Ohm	40 Ohm	20 Ohm
Concrete 1:5	400 Ohm	-	-	-	160 Ohm	80 Ohm	40 Ohm
Moist gravel	500 Ohm	160 Ohm	80 Ohm	48 Ohm	200 Ohm	100 Ohm	50 Ohm
Dry sandy soil	1000 Ohm	330 Ohm	165 Ohm	100 Ohm	400 Ohm	200 Ohm	100 Ohm

Fig. 4.8 Copper plate used for plate earthing

Types of earthing on the basis of electrical system

There are four types of earthing, which are as follows.

Plate earthing

In plate earthing system (as shown in Figs. 4.8 and 4.9), a plate made of either copper with dimensions 60cm × 60cm × 3.18mm or galvanised iron (GI) of dimensions 60cm × 60cm × 6.35 mm (2ft × 2ft × ¼ inch) is buried vertically into the earth (earth pit), which should not be less than 3m (10ft) from the ground level.

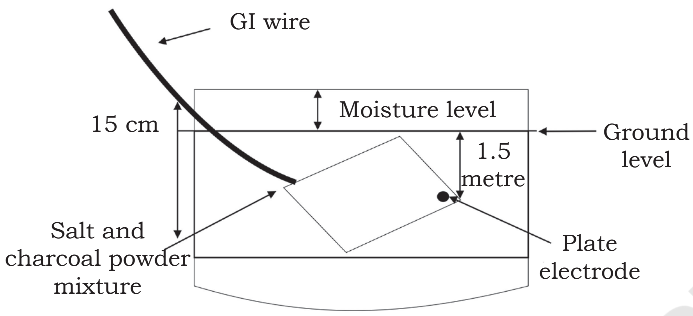

Fig. 4.9 Plate earthing

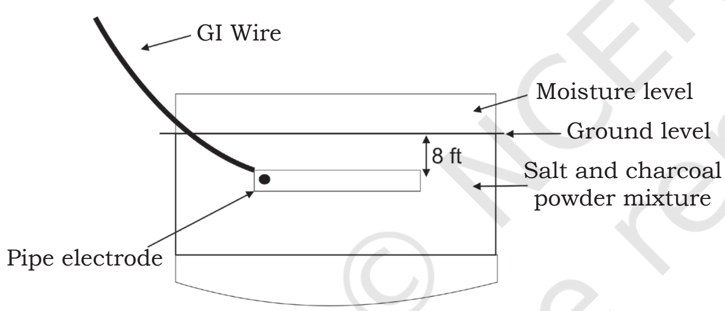

Fig. 4.10 Pipe earthing

Pipe earthing

In this kind of earthing system, a galvanised steel rod and perforated pipe of approved length and diameter is placed vertically into the wet soil. It is the most common system of earthing (as shown in Fig. 4.10).

The size of the pipe used depends on the magnitude of current and the type of soil. The dimension of the pipe is, usually, 40mm (1.5in) in diameter and 2.75m (9ft) in length for ordinary soil or greater for dry and rocky soil. A mixture of charcoal and salt of 10 kg each can be put into the pit to increase the conductivity of the soil. The moisture of the soil will determine the length of the pipe to be buried but, usually, it is 4.75m (15.5ft).

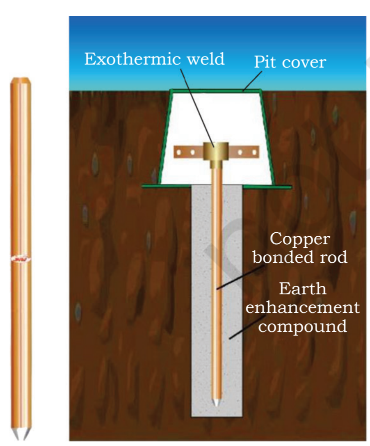

Fig. 4.11 Rod earthing

Rod earthing

Also known as 'fire earthing', it is the same as pipe earthing (Fig. 4.11). A copper rod of 12.5mm (1/2 inch) diameter or a rod 16mm (0.6in) diameter made of galvanised steel or hollow section, and 25mm (1inch) diameter of GI pipe of length above 2.5m (8.2 ft) are buried in upright position into the earth manually or with the help of a pneumatic hammer. The length of embedded electrodes in the soil reduces earth resistance to a desired value.

Strip or wire earthing

In this method of earthing, strip electrodes of cross section not less than 25×1.6mm (1×0.06 inch) is buried in horizontal trenches at a minimum depth of 0.5m. If copper with a cross section of 25×4mm (1×0.15 inch) is used for galvanised iron or steel, the dimension will be 6mm sq (Fig. 4.12).

If at all, round conductors made of galvanised iron or steel are used, their cross section area should not be too small, say less than 6mm^2. The length of the conductor buried in the ground will give sufficient earth resistance and this length must not be less than 15m. This type of earthing is mostly used in transmission lines

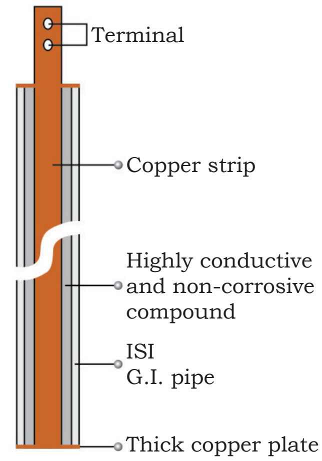

Fig. 4.12 Strip earthing

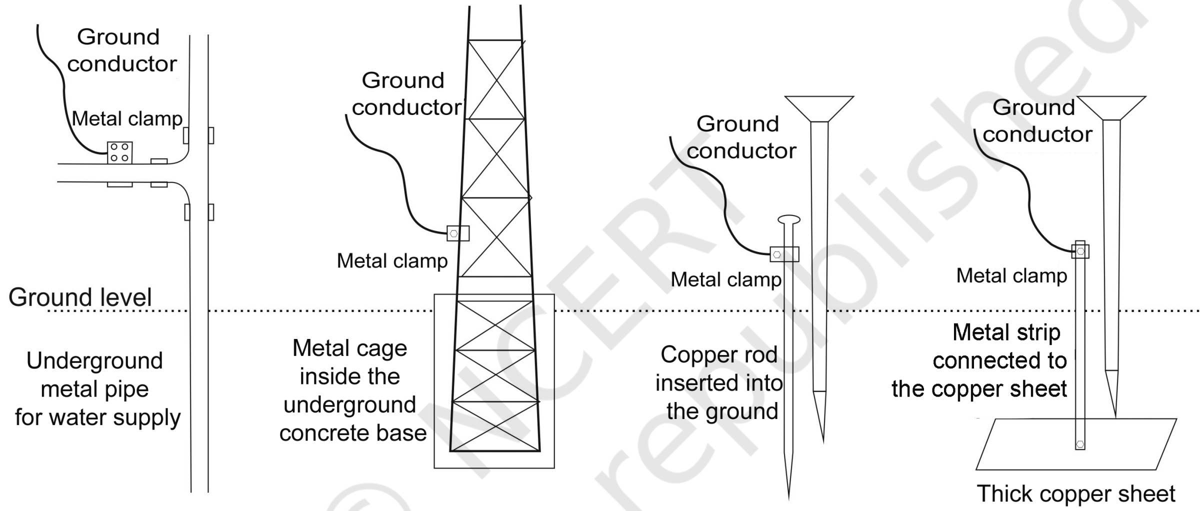

Fig. 4.13 Various ways of earthing

Lightning arrester

Lightning is a form of visible discharge of electricity between rain clouds or between a rain cloud and the earth. The electric discharge is seen in the form of an arc, sometimes several kilometres long, stretching between the discharge points.

When the electrical potential between two clouds or between a cloud and the earth reaches a sufficiently high value, the air becomes ionised along a narrow path and results in a lightning flash.

The possibility of discharge is high on tall trees and buildings rather than the ground. Buildings are protected from lightning by metallic lightning rods extending to the ground from a point above the highest part of the


Fig. 4.14 Lightning arrester

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roof. A lightning arrestor has a pointed edge on one side and the other side is connected to a long thick copper strip, which runs down the building. The lower end of the strip is earthed. When lightning strikes, it hits the rod and current flows down through the copper strip. This rod forms a low-resistance path for the lightning discharge and prevents it from travelling through the structure itself.

The lightning arrestor protects the structure from damage by intercepting flashes of lightning and transmitting the current to the ground. Since lightning strikes tend to strike the highest object in the vicinity, the rod is placed at the apex of a tall structure. It is connected to the ground by low-resistance cables. In case of a building, soil is used as the ground, and in case of a ship, water is used. A lightning rod provides a cone of protection, which has a ground radius, approximately, equal to its height above the ground.

A lightning rod or lightning conductor is a metal rod mounted onto a structure and intended to protect the structure if lightning strikes. If lightning hits the structure, it will preferentially strike the rod and be conducted to the ground through a wire, instead of passing through the structure, where it could lead to a fire or cause electrocution. Lightning rods are also called 'finials', 'air terminals' or 'strike termination devices'.

In a lightning protection system, a lightning rod is a single component of the system. The lightning rod requires a connection to earth to perform its protective function. Lightning rods come in different forms, including hollow, solid, pointed, rounded, flat strips or even bristle brush-like. The main attribute common to all lightning rods is that they are all made of conductive material, such as copper and aluminium. Copper and its alloys are the most common material used in making lightning protection rods.

Features

- A lightning arrester can be used for safeguarding a structure from being struck by lightning.
- It can be installed at all corners of the building at every 7.5m distance from each other and at all periphery and elevated positions.

- All lightning arresters are interconnected by 25×6mm GI strip at every 7.5m.
- One down conductor GI strip of 25×6mm is routed to one dedicated earth pit and all earth pits must be interconnected by GI strip below the ground level.

Usage

Lightning arresters can be used in the following.

- Chimneys
- High-rise buildings
- Important places, such as monuments, etc.
- Residential building, hotels, etc.

Check Your Progress

A. Multiple choice questions

1. What is the specification of GI earth plate?
   (a) 60 cm × 60 cm × 3 mm
   (b) 60 cm × 60 cm × 6 mm
   (c) 60 cm × 60 cm × 4 mm
   (d) 60 cm × 60 cm × 5 mm
2. What is the amount of charcoal and salt needed for GI pipe earthing?
   (a) Charcoal 5 kg, salt 8 kg
   (b) Charcoal 10 kg, salt 8 kg
   (c) Charcoal 10 kg, salt 10 kg
   (d) Charcoal 5 kg, salt 5 kg
3. The size of the earth or ground wire is based on __________________.
   (a) the maximum fault current being carried through the ground wire
   (b) the rated current carrying capacity of the service line
   (c) soil resistance
   (d) Both (a) and (c)
4. Earth or ground wire is made of ________________.
   (a) copper
   (b) aluminium
   (c) iron
   (d) galvanised steel
5. Generally, grounding is provided for ____________.
   (a) the safety of the equipment
   (b) the safety of the operating personnel
   (c) Both (a) and (b)
   (d) None of the above

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6. Ground resistance should be designed such that ____________________.
   (a) grounding resistance is as low as possible
   (b) grounding resistance is as high as possible
   (c) grounding resistance is always zero
   (d) None of the above
7. The objective of earthing or grounding is __________.
   (a) to provide as low resistance as possible to the ground
   (b) to provide as high resistance as possible to the ground
   (c) to provide flow of positive, negative and zero sequence currents
   (d) None of the above
8. Moisture content in the soil _____________ the earth's soil resistance.
   (a) increases
   (b) decreases
   (c) does not affect
   (d) None of the above
9. Factors on which soil resistance depends is/are ________________.
   (a) depth of the electrode
   (b) moisture
   (c) NaCl (salt)
   (d) All of the above
10. What type of earthing is used by transmission lines?
    (a) Plate earthing
    (b) Rod earthing
    (c) Strip earthing
    (d) Both (a) and (c)
11. Average resistance of human body is _________________.
    (a) 200 Ohm
    (b) 1000 Ohm
    (c) 1500 Ohm
    (d) 2000 Ohm
12. Which type of earthing is also called 'fire earthing'?
    (a) Plate earthing
    (b) Rod earthing
    (c) Strip earthing
    (d) All of the above

B. Fill in the blanks

1. The algebraic sum of the resistances of earth continuity conductor, earthing lead, earth electrode and earth is called ________________.
2. The ________________ protects a structure from damage by intercepting flashes of lightning and transmitting the current to the ground.
3. The minimum distance between two earth electrodes must be ________________.

4. Collect all wires in a metallic pipe from the earth electrode. Make sure that the pipe is ________________ above the ground surface.
5. Strip electrodes of cross section not less than ________________ are buried in horizontal trenches of a minimum depth of 0.5m.

C. State whether the following statements are True or False

1. Soil resistance can be improved by using NaCl (salt).
2. An earth and ground wire is made of iron.
3. Earthing increases the resistance of the conductive path.
4. Earthing is used to provide supply voltage to an equipment.
5. The average resistance of the human body is 1500 Ohm.
6. In GI pipe earthing, 5 kg charcoal and 5 kg salt are required.
7. In transmission lines, plate earthing is used.
8. Strip earthing is also known as fire earthing.
9. For large power stations, the earthing resistance value is 0.5 Ohm.
10. The connection between electrical installation systems via conductor to the buried plate in the earth is known as earthing.

D. Short answer questions

1. What is earthing?
2. Why is earthing required?
3. Write down some applications of earthing.

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